RECORDS OF NIGHT CLOUDINESS FOR ASTRONOMERS

By Alexander McAdie

When in those golden days of yore in the land of hope and progress we walked and talked[1] of things great and small, the Nestor of science on the Pacific Coast, the head of the Lick Observatory, remarked:

"This would be a good world for the astronomer, if there was no atmosphere!"

Now we humble aerographers have been trying to find out something concerning this very shallow shell of air that surrounds the planet; but as yet we have done very little to help the astronomer; and the thought will come that perhaps progress would be greater if astronomers themselves would lend a hand. This paper is a plea for such effort.

The atmosphere is only about 100 kilometers in depth and for practical purposes we need consider only the lowermost tenth of that. At the 10 kilometer level we are above the clouds. Some few cumulo-nimbi poke their heads higher on summer afternoons, but these do not interfere with the work of the astronomer.

In the following table the mean cloud heights as determined at Blue Hill in various ways (theodolite, sounding balloon, pilot balloon and kites) are given.

CLOUD HEIGHTS

NAME	MEAN HEIGHT IN METERS		DEFINITION
	Summer	Winter	
Cirrus	9900	8050	Thin, fibrous, detached, feather-like clouds.
Cirro-stratus	8750	7850	Thin, white veil, more or less fibrous.
Cirro-cumulus	7606	6992	Small, white cottony balls in flocks,
Alto-cumulus	3195	2931	Large, more or less rounded balls. flat disks, or rolls or fleecy flocks.
Alto-stratus	6481	2930	A gray or blue veil exhibiting in the vicinity of the Sun or Moon.
Strato-cumulus	1957	1830	Large gray balls; or rolls in close contact[2].
Cumulus	1473	1381	Thick clouds whose summits are dome-like with protuberances; bases flat.
Fracto-cumulus	1235	1220	Flat, broken clouds of the cumulus type.
Cumulo-nimbus	1202	1552	Massive clouds from which showers fall.
Nimbus	712	....	A dense, dark sheet of ragged cloud from which rain or snow usually falls.
Stratus	583	503	Lifted fog in horizontal stratum.

[1]See Presidential Address, *Publ. Astron. Soc. Pac.*, **26**, No. 153, Jan., 1914.

[2]See *Principles of Aerography*, p. 117; also Clayton's "Discussion of Cloud Observations," Harvard Observatory *Annals*.

But there is now a more direct way of determining cloud heights and velocities, namely, by airplane, which enables us to get to the cloud and not only measure the bottom of the cloud but the top as well.

Aviators can climb quickly to the very top of cloudland, that is, to the bottom of the stratosphere, the beginning of the major temperature inversion. And let it be noted that inversions must be reckoned with in all questions of atmospheric refraction. Perhaps if we knew a little more about inversions at times of total solar eclipses, we could account for a portion of the shift of star images. Be that as it may, during the next eclipse, provision should be made for observations of air temperature and density at different levels, by means of airplanes.

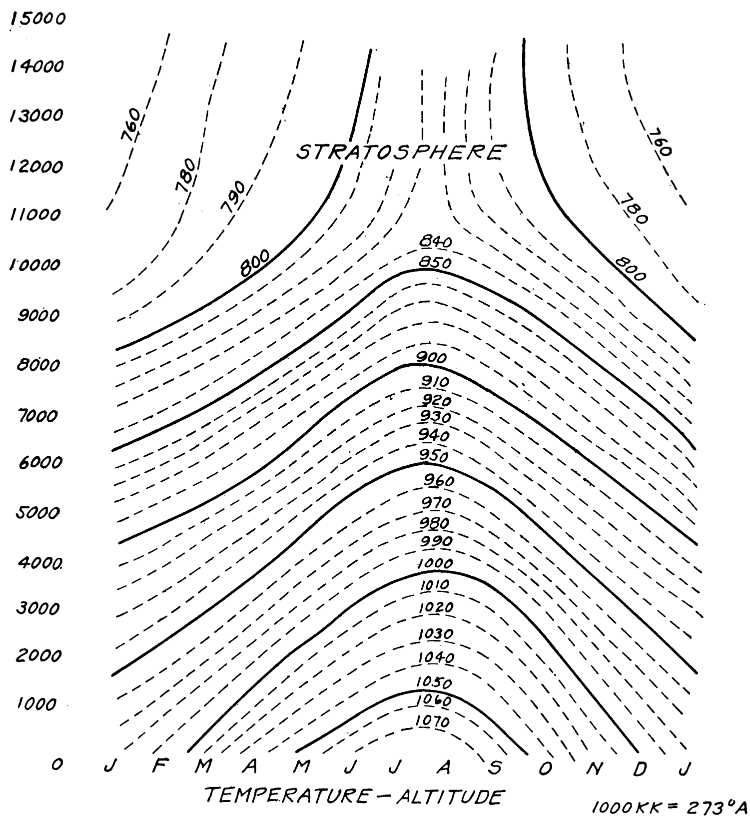

FIG. 1

Computing the heights reached by two American airmen (record heights) and correcting the altimeter readings for temperature, humidity, gravity variation with altitude and latitude, I make the elevation of Major Schroeder of the Air Service, February 27th, 1920, at McCook Field, to be 9915 meters (32527 feet). This differs slightly from the Bureau of Standards' round number; but the data used are those kindly supplied by the Bureau. I make Roland Rohlfs' best height (September 18, 1919, at Mineola) 9645 meters (31646 feet).

We have here a winter and a summer flight.

As we all know, an adiabatic temperature gradient, called abroad "the lapse rate" is 30.26 kilograds (9.87°A) per kilometer. But such a rate seldom prevails, and we find in moderately saturated mixture of air and vapor in stable condition, an average lapse of 22 kilograds (6°A). A good idea of the temperature at levels up to the stratosphere for a year can be had by inspection of Fig. 1 (Temperature—Altitude) in which temperature is expressed on the Kelvin Kilograd scale. The isotherm of 1000 for example, is the freezing point (32°F) and one sees that even in midsummer such a temperature is found at 4000 meters.

Similar charts are available for pressure and density. But for the special purpose of the astronomer, namely, the forecasting of night cloudiness, we need, particularly, charts showing the distribution of water vapor, its pressure in kilobars and its weight in kilograms per unit volume of space, that is, its density.

Some idea of the annual distribution of water vapor in units of force is given by Fig. 2.

Cloudiness is simply the process of making visible the previously invisible water vapor. Cooling is the effective agency and this cooling may be brought about by lifting, by radiation, by mixing or by conduction. In lifting a given volume of air and vapor, there is expansion due to decreased pressure, and hence cooling. The astronomer, therefore, must regard all anabatic (up-rising) winds as potential cloud builders. The second operative cause of cooling namely, radiation, is all important. For a maximum effect, still air and dust-free air are needed. Much of the cloudiness of low levels, the valley fogs, and the early morning stratus of coastal sections, are caused by radiation cooling during the night hours and consequent saturation temperatures. The third cause, mixing, is more apt to be associated with higher level clouds and the movement of

air either horizontally or vertically. We know comparatively little about the vertical winds; but horizontal winds we partially measure. Fig. 3 shows average values at different levels, also the "structure" of the air under different conditions such as the sea-breeze or the approach of a cyclone from the south, "sea-turn."

It is evident that high velocities are found just under the stratosphere.

Some mean velocities determined from cloud drift are:

10000	meters	45.6 m/s	(102 m/h)
10400	meters	40.2 m/s	(89.9 m/h)
10800	meters	40.0 m/s	(89.5 m/h)
11200	meters	37.8 m/s	(84.6 m/h)

Among the Blue Hill Cloud records is one made February 21, 1897, in the afternoon, showing a cirro-stratus, elevation 9946 m., moving from 270 (W) with an apparent velocity of 84 m/s (188 m/h). Again on the morning of February 25th, cirrus, elevation

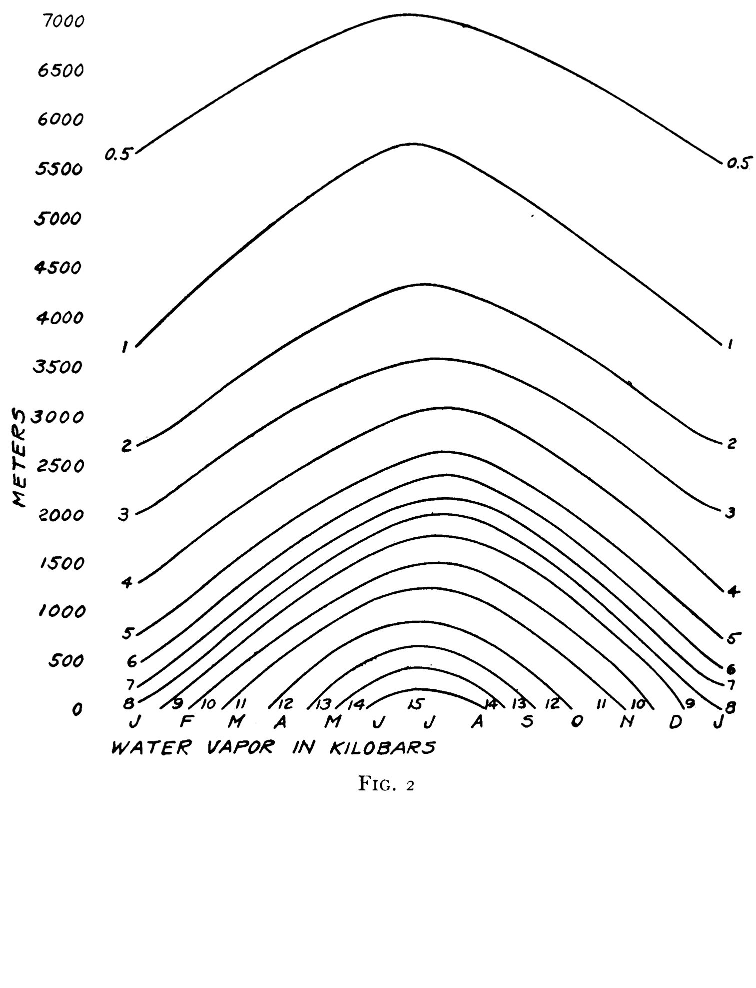

FIG. 2

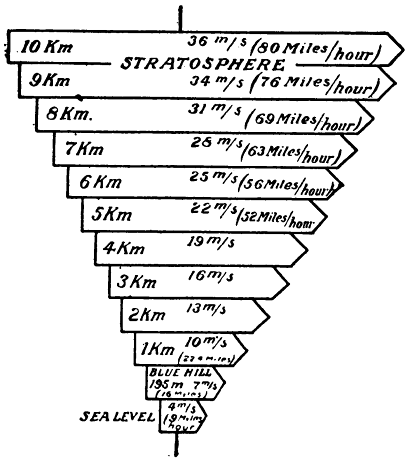

FIG. 3 (a)
Increase of Velocity with Elevation

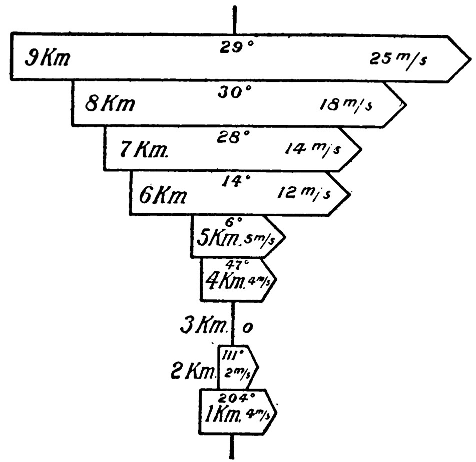

FIG. 3 (b)
Sea-Breeze Structure

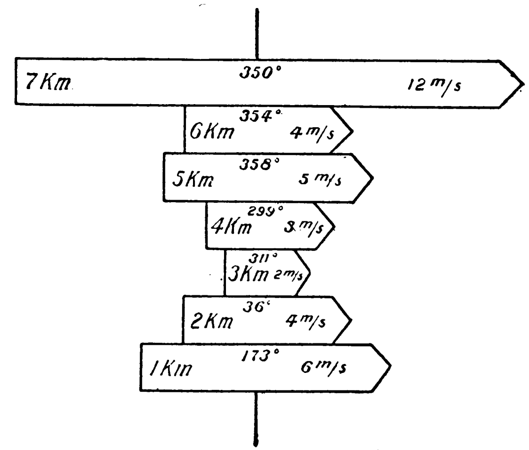

FIG. 3 (c)
Sea-Turn Structure

9610 m., moves from 225 (WSW) with a speed of 94 m/s (210 m/h). Finally the banner record for air speed, a cirrus on October 12th, 1891, moving 102.6 m/s or 228 miles per hour.

It is something of a problem to know in advance the probable level of cloudy condensation, for there are many independent variables. Still we must try to solve it. We are learning that air falls as well as rises. It is the falling which frequently dissipates the cloudiness, for here is dynamic heating. Falling air, however, often fails to reach the ground, being fanned out in the lower levels. So we get inversions and sheets of cloud with much warmer clear weather just above the sheet, generally wide spread.

If we except the familiar sea fog brought in by the low level winds, the fog or cloud that bothers astronomers most is this low level inversion cloud. Happily the astronomers on the Pacific Coast can get above many of the cloud sheets; but their brethren elsewhere suffer.

Now why should not all astronomical observatories maintain autographic cloudiness recorders? This suggestion may shock astronomers, for surely they of all people—these pilgrims of the night—know and note in their records the conditions favorable or unfavorable for work. Perhaps so; but how many observatories have in operation so simple a device as a Pole-Star Recorder? This ininstrument, devised by an astronomer, the late Professor E. C. Pickering, in 1885, has been in operation at Blue Hill since 1888, having been used before this at Harvard College Observatory. The writer may be mistaken and hopes he is; but so far as known, for over thirty years the only record of night cloudiness has been the one at Blue Hill. In official weather reports such a thing as a night cloudiness record does not exist. This is true abroad as well as at home. Some tale of the night must be kept, but chiefly this is based on the Night Watchman's or the Early Milkman's say so.

The principle of the instrument is simple and the original cost and expense of maintaining, quite small. *Polaris* and *δ Ursae Minoris* thru a long focus lens give on a small photographic plate star trails; full, if the night is clear, broken, if the night is intermittently cloudy, and no trail if entirely cloudy. For details of the instrument see references[3].

[3] *Principles of Aerography*, McAdie, page 133, for this and also a Moonlight intensity recorder.
B. C. Kadel, in *Monthly Weather Review*, Vol. 47, page 154, March 1919.
S. P. Fergusson, *Quart. Journ. Roy. Meteor. Soc.*, Vol. XXXI, page 309, October, 1905.

And now comes the Royal Observatory at Greenwich in this year of grace 1920, and installs a Pole-Star Recorder; and the meteorologists of the United Kingdom return thanks. One should read the discussion in the *Quart. Journ. Roy. Meteor. Soc.* for July, 1920, p. 243, to taste the humor of the situation, for it had evidently been forgotten by all that Fergusson, fifteen years ago, had published in that very journal a full account of the instrument.

The Astronomer Royal will, we hope, proceed now to add to the equipment of the Observatory an airplane.

The University Observatory at Chicago has also recently installed a Pole-Star Recorder. How many observatories on the Coast are giving attention to these problems of night cloudiness? For a knowledge of air structure, night cloudiness is better than day cloudiness, for we are free from the disturbing effect of solarization. The Sun, so generally regarded as a cloud dispeller, can also, as the late Dr. John Aitken showed, act at times as a cloud builder. As Sir Napier Shaw points out records of night cloudiness are preferable to sunshine records in studying the dynamics of the atmosphere.

May we then venture to suggest that astronomers wait no longer for aerographers to solve the problems of night cloudiness; but make a start, even if only by the installation of so simple a device as a Pole-Star Recorder? In time other instruments must come, simple too, but telling of any interception by means of cloud of the radiant heat from the Earth. Astronomy is in its essence a reaching out from Earth into space; why then shall we not reach out and record the temperature, pressure, density, vapor content, heat gain and heat loss, in the different levels of our own atmosphere, especially so since these bear directly upon the efficiency of every observatory?